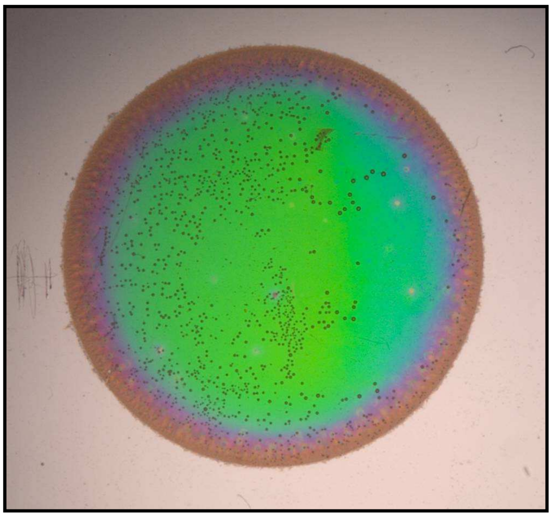
Development of Chemical Gradients across Porous Silicon Sensors



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Abstract

This thesis investigated the formation of compositional gradients across 0.5 – 1 cm of porous silicon layers which had thicknesses of 2 – 10 µm. These compositional gradients were then characterised, and their potential use as vapour sensors was probed. Surface composition gradients have been reported on flat surfaces, but this is the first time that they have been reported on a three-dimensional material with controlled pore geometry.

Chemical gradients have been generated across the surface of porous silicon by performing electrochemical attachment of organohalides with an asymmetric electrode arrangement, and by chemical hydrosilylation of alkenes in the presence of a diffusion gradient of diazonium salts across the porous silicon surface. Samples with electrochemical gradients of methyl, pentyl acetate, and decyl and using chemical hydrosilylation with gradients of undecanoic acid and decyl groups. The latter four gradient-modified porous silicon types have been 'endcapped' with methyl groups to give improved stability and greater hydrophobicity. The pentyl acetate and undecanoic groups have been converted into pentanol and undecanoate groups respectively to increase the hydrophilicity of these porous silicon surfaces. The gradients have been characterised using two-dimensional FTIR microspectrophotometry and water contact angle measurements.

The interaction of these gradient porous silicon samples with ethanol, heptane, toluene and 2-hexanol vapours have been monitored either by UV-Vis reflectance spectroscopy at selected points across the surface or more globally using a digital camera. The undecanoate gradient porous silicon sample showed a large difference in optical response between the undecanoate end and the methyl end of the gradient when exposed to water vapour, showing that imposition of a chemical gradient can alter the sensing character of porous silicon in a controllable manner.

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Abbreviations

AAS	Atomic absorption spectroscopy
AFM	Atomic force microscopy
ATR	Attenuated total reflectance
BBD	4-bromobenzenediazonium tetrafluoroborate
CCD	Charge coupled device
e^-	Electrons
EDAX	Energy dispersive X-ray spectroscopy
EDS	Energy dispersive spectroscopy
EOT	Effective optical thickness
FBD	3,4,5-trifluorobenzenediazonium tetrafluoroborate
FEG	Field emission gun
FFT	Fast Fourier Transform
FTIR	Fourier Transform infrared spectroscopy
FWHM	Full width at half maximum
GC-FID	Gas chromatograph – flame ionisation detector
GC-MS	Gas chromatograph – mass spectrometer
h^+	Holes
HF	Hydrofluoric acid
HPLC	High pressure liquid chromatography
IR	Infrared
LCTF	Liquid crystal tunable filter
MCT/A	Mercury Cadmium Telluride detector
NMR	Nuclear magnetic resonance spectroscopy
PDMS	Poly dimethylsiloxane
PID	Photoionisation detector
PL	Photoluminescence
ppm	Parts per million
PSi	Porous Silicon
RF	Radio frequency
RGB	Red green blue
SAM	Self assembled monolayer
SEM	Scanning electron microscopy
SIFT-MS	Selected ion flow tube mass spectrometer
SIMS	Secondary ion mass spectroscopy
STM	Scanning tunnelling microscopy
THF	Tetrahydrofuran
UV	Ultra violet
UV-Vis	Ultra violet – visible spectroscopy
VOCs	Volatile organic compounds
XPS	X-ray photoelectron spectroscopy